An active adaptive management case study in Ontario boreal mixedwood stands

by G. Blake MacDonald[1] and James A. Rice[1,2]

Active adaptive management has recently been advocated for efficiently reducing resource management uncertainties, but no documented applications to forestry issues exist in Ontario. This paper reports the experience of a diverse partnership applying active adaptive management to improve techniques for obtaining desired boreal mixedwood structure and composition in northeastern Ontario. Institutional and economic barriers have been more limiting than technical barriers. Building and maintaining the partnership have required considerable effort, and opportunities for conflict were greatest in the assessment and design steps of the adaptive management cycle. The partnership has maintained its progress by promoting flexibility, trust, and consensus-building. This study demonstrates that classical adaptive management can be simplified for application in local management units. A broader application of active adaptive management in Ontario will require senior decision-makers to endorse a strategy that includes staff retraining, admission of management uncertainties, cooperation among management agencies, stability of long-term funding, encouragement of innovation, and regular adjustment of policies and practices.

Key words: consensus-building, designed learning, forest management policies, modelling, monitoring, partnerships, response indicators

L'aménagement d'adaptation active a récemment été invoqué pour réduire de façon efficace les incertitudes dans l'aménagement des ressources, mais aucune application documentée dans le secteur forestier n'existe en Ontario. Cet article fait état de l'expérience d'un partenariat diversifié qui applique l'aménagement d'adaptation active pour améliorer les techniques d'obtention de la structure et de la composition désirées des peuplements mélangées boréaux du nord-est de l'Ontario. Les obstacles institutionnels et économiques ont engendré plus de difficultés que les obstacles techniques. L'élaboration et le maintien du partenariat ont nécessité beaucoup d'effort et les possibilités de conflit ont atteint un sommet lors des étapes d'évaluation et de conception du cycle d'aménagement d'adaptation. Le partenariat a pu poursuivre son développement par la promotion de la flexibilité, de la confiance et l'élaboration de consensus. Cette étude démontre que l'aménagement d'adaptation classique peut être simplifié pour une utilisation au sein d'unités locales d'aménagement. Une utilisation plus étendue de l'aménagement d'adaptation active en Ontario nécessitera que les preneurs de décision à des niveaux supérieurs endossent une stratégie qui comprend la formation du personnel, l'admission d'incertitudes d'aménagement, la coopération entre les organismes d'aménagement, la stabilité à long terme du financement, l'encouragement de l'innovation et l'ajustement périodique des politiques et des pratiques.

Mots-clés: élaboration de consensus, apprentissage ciblé, politiques d'aménagement forestier, modélisation, surveillance, partenariats, indicateurs de réaction

Introduction

The potential for conflict among forest resource users is increasing as accessible wood supplies diminish, regulators and environmentalists demand more sustainable practices, and a growing population seeks access to managed forest lands for a range of recreational activities. Rapid increases in our understanding of forest ecosystem responses to management are required as the basis for developing guidelines that can be supported by all user-groups. However, forest management uncertainties are often slow to be resolved because of the time needed to confirm treatment effects in complex biophysical systems (Lee 1999, Stankey *et al.* 2003).

Active adaptive management is an option for building consensus among diverse stakeholders and efficiently advancing practical knowledge. Although active adaptive management of natural resources has been reported in North America (Rempel *et al.* 1997, Stankey and Shindler 1997, Taylor *et al.* 1997, MacDonald *et al.* 1999, Spence *et al.* 1999), successful initiatives are rare (Lee 1999) and there are no documented applications to forestry issues in Ontario. The objectives of this paper are to report experience gained applying an active adaptive management approach to boreal mixedwood silviculture and to recommend actions for expanding its use in Ontario. Although issues addressed are specific to northeastern Ontario, the experience with active adaptive management may be instructive for resource managers and researchers in other jurisdictions.

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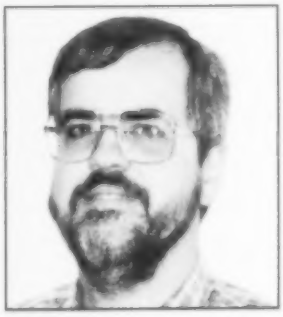

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Overview of Adaptive Management

Adaptive management is a formal process for improving management policies and practices by learning from their outcomes (Taylor *et al.* 1997). In contrast to typical research trials, it considers the behaviour of entire systems, rather than component processes (Holling 1978, Duinker and Trevisan 2003) and involves resource managers and/or policymakers as key participants in the entire process (Taylor *et al.* 1997). The approach is derived from industrial and engineering applica-

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tions, where assessment and adaptation mechanisms function during project evolution (Holling 1978). Adaptive management allows resource managers to implement their practices responsibly despite uncertainty and disagreement (Taylor *et al.* 1997).

Resource decision-making should be viewed as a cyclical learning process, rather than a linear process resulting in a legislated or recommended practice. The term "best practices" is often inappropriate because the superlative connotes treatments that cannot be improved. Since uncertainty surrounding the behaviour of natural resources increases the risk in many management decisions (Walters 1986), adaptive management has been proposed as a system to reduce key uncertainties (Taylor *et al.* 1997).

Ontario formally recognizes the need to improve its resource stewardship through adaptive management (OMNR 2003a). In Ontario's forest management planning process, local stakeholders define desired objectives and strategies to achieve those objectives (OMNR 1996). This process leads to the development of candidate silvicultural treatment packages that are screened to a single optimum treatment package for each forest unit. Following implementation of the forest management plan, the effectiveness of the treatment package is monitored and assessed to provide a basis for adjusting it in subsequent plans. The implementation and monitoring of a single management alternative identifies this process as passive adaptive management. This approach can advance learning if the objectives and anticipated outcomes of strategies are clearly defined, the monitoring plan is developed before management actions commence, and all aspects of the management alternative are implemented operationally (MacDonald *et al.* 1997).

In contrast, active adaptive management tests the effectiveness of several alternative policies or practices in each forest unit by implementing and monitoring them simultaneously. Both passive and active adaptive management involve a sequence of six steps (Taylor *et al.* 1997): *assess*, *design*, *implement*, *monitor*, *evaluate*, and *adjust* (Fig. 1). Active adaptive management yields more reliable information and accelerates learning by developing multiple hypotheses (alternative policies or practices) and an experimental framework in the design step, and ensuring analytical rigour in the evaluation step. At least one of the active adaptive management alternatives should be designed for strong improvement in resource performance, i.e., shift it beyond the range of historical experience (Walters 1986). Some of the alternatives may require reducing immediate harvest levels, accepting risks of ecosystem damage, or introducing unaccustomed variation in resource levels (Walters 1986).

Knowledge gaps in resource management are addressed most effectively through experiments conducted at operational scales because many critical ecological processes are not evident at small spatial scales (Walters 1997a). Fine-scale research projects cannot quantify variation from sources such as climate, topography, soils, stand structure, and equipment operators, and thus may not adequately answer resource management questions. An advantage of active adaptive management is that it treats policies or practices as experiments at the scale of normal operations.

Although adaptive management links science and management (Gray 2000), it is inappropriate for a science agency to lead or coordinate an entire adaptive management initiative. Adaptive management should be driven by resource planners and managers, with researchers providing a supporting role in designing the approach, analyzing the data, and interpreting the results (Nyberg 1999).

The Stand-Level Adaptive Management (SLAM) Case Study

A case study was developed to reduce boreal mixedwood management uncertainties and to assess the merits of applying active adaptive management more widely in Ontario's forest management planning process. Government, industry, non-profit, and academic partners have made long-term commitments and accepted clearly defined roles related to the adaptive management framework of this project (Table 1). Project implementation was facilitated by substantial funding from Ontario's Living Legacy Trust[3], in addition to the support provided by all partners.

A case study approach has been recommended for Ontario because it would develop local expertise, document costs, problems, and benefits, and identify situations where active adaptive management is inappropriate or infeasible (MacDonald *et al.* 1997). The effectiveness of case studies for exploring new approaches to sustainable forest management has been demonstrated (McGregor Model Forest Association 1997).

By incorporating experimental timber harvesting and regeneration into the planning and operations of two forest companies in northeastern Ontario, this case study is designed to improve understanding of boreal mixedwood ecology and silviculture. Treatments to achieve productive mixtures of conifers and hardwoods are being applied in boreal mixedwood stands on the limits of Abitibi-Consolidated Inc. east of Cochrane and Domtar Inc. west of Gogama. Contrasting approaches are being compared (e.g., blended mixtures vs. patchwork mosaics of regenerating species, partial cutting vs. herbicide application, shade-tolerant vs. shade-intolerant conifer regeneration) to increase learning potential. Treatment effectiveness is being assessed by monitoring silvicultural, economic, and ecological indicators.

New knowledge will be transferred through peer-reviewed publications, technical reports, newsletters, field tours, demonstration areas, workshops, extension, and web site, to address the needs of policymakers, forest managers, the science community, and the public. Recommendations on applying active adaptive management in forestry will also be developed when all steps in the cycle have been completed. An important goal is to close the adaptive management cycle by incorporating new understanding into provincial silvicultural guidelines and forest management plans.

Detailed information about study sites, field methods, and analytical approaches has been published elsewhere (MacDonald *et al.* 2003). This paper focuses on the advantages and disadvantages of using an active adaptive management framework for the study.

Assessing the Problem

Although the approach in this case study was less formal than the structured workshops advocated by Holling (1978),

[3]The Living Legacy Trust is a $30 million fund established by the Province of Ontario to support natural resource management projects in northern Ontario. Trust assets are managed by an independent Board of Directors representing various stakeholder groups.

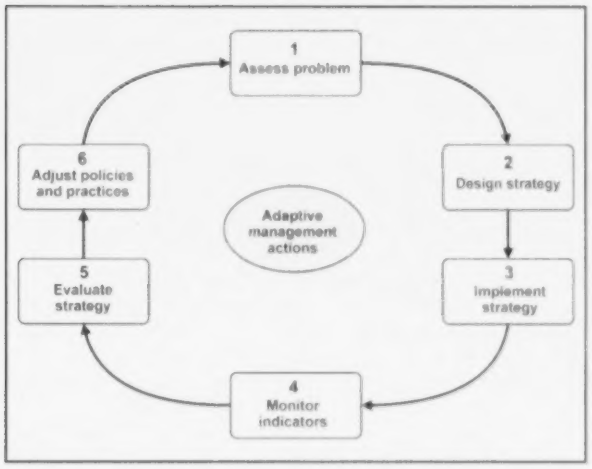

Fig. 1. Essential steps in the adaptive management cycle.

it was effective for determining the highest-priority resource values, relevant management questions, innovative treatments to apply, and response indicators to monitor. Following exploratory meetings and discussions, a three-day facilitated planning workshop was convened in December 2000 for potential partners in an adaptive management case study. Participants agreed that the key uncertainty was how to achieve desirable boreal mixedwood stand structures economically. Consensus also emerged on the importance of enhancing biological diversity and other values through proactive boreal mixedwood management. All partners accepted that increased understanding of boreal mixedwood ecology and stand dynamics is necessary to support the development of reliable management guidelines. However, reaching consensus on the relative importance of economic and ecological values, and hence appropriate indicators to monitor, was challenging. For example, industry representatives emphasized sustainability of wood supply, while provincial government representatives emphasized sustainability of ecosystem structure and function.

In developing management objectives, workshop participants identified present forest conditions for which management uncertainties exist, defined a desirable future forest condition, and listed potential management actions for achieving it. For example, to ensure adequate hardwood crop tree regeneration, participants agreed that:

- Prior to treatment, the stands should contain at least 20% overstory trembling aspen (*Populus tremuloides* Michx.).
- Balsam fir (*Abies balsamea* [L.] Mill.), which is not a preferred crop species in Ontario, should not be abundant in the canopy or understory.
- Understory stocking of desired conifer species should be 40% or higher for natural regeneration options, and less than 40% for artificial regeneration options.
- Future stands should contain approximately equal proportions of marketable conifers and hardwoods in the overstory (40 to 60% hardwood basal area, at 60 years of age).

To move from the present stand condition to a desirable future condition, participants proposed variations in type, timing, intensity, pattern, and frequency of harvesting, site preparation, regeneration, and tending. They agreed to address uncertainties surrounding which management actions are silviculturally effective, economically feasible, and ecologically acceptable.

Considering the many political, social, economic, institutional, and technical challenges typical of adaptive management initiatives (MacDonald *et al.* 1999), opportunities for success were enhanced by limiting the scope of this case study. For example, potential future forest conditions and silvicultural treatments were limited to those with the most operational relevance and highest management uncertainty. Furthermore, the inference population was strictly defined as ecosites capable of supporting productive boreal mixedwood stands in northeastern Ontario.

Designing a Strategy

Participants in the planning workshop and follow-up task teams developed a strategy to test contrasting options for obtaining the desired mixedwood structure. The strategy involved surveying the literature for studies on similar management uncertainties elsewhere, assembling existing data and expert opinion, defining details of candidate treatment packages, generating hypotheses about treatment effects, selecting a subset of treatments to test operationally, identifying appropriate indicators to monitor, and designing treatment layout and monitoring.

The design step in the adaptive management cycle is challenging because it requires considerable creativity and may generate conflict among stakeholders. Adequate time should be allocated to this step because the complexity of adaptive management projects and the effort required to plan and implement them tend to be underestimated (McGregor Model Forest Association 1997), and implementing treatments prior to clearly articulating relevant questions about resource responses will not produce useful information (Holling 1978).

Treatment packages

In identifying potential treatments, partners considered published mixedwood approaches in other jurisdictions, expert opinion, knowledge of local operational constraints, and qualitative predictions of treatment outcomes by workshop participants. Although treatments were designed to probe the extremes in the range of appropriate options rather than simply refine current practices, operational factors necessitated compromises on final treatment selection. For example, forest industry partners were unable to deviate dramatically from standard practices because they were constrained by the capabilities of existing equipment and operators. Treatments had to be kept practical, operationally relevant, and economically feasible. Industry partners were not interested in testing treatments that might increase wood costs by slowing operations or reducing harvest volumes.

Sufficient contrast was included among treatments to advance knowledge of boreal mixedwood management in Ontario. The intention was to promote learning by evaluating broad treatment directions, rather than calibrating precise details of a recommended treatment package. For example, silvicultural, economic, and ecological effects are being compared among blended mixtures, patchwork mosaics, and standard conifer plantations, and among pre-harvest herbicide spraying, post-harvest spraying, and 50% partial cutting in lieu of spraying.

The initial design included treatments for natural (advance) and artificial conifer regeneration at both the Abitibi-Consolidated and

Table 1. Overview of the roles of partner organizations in the Stand-Level Adaptive Management case study (adapted from MacDonald *et al.* 2003)

Organization	Roles
Abitibi-Consolidated and Domtar	Implement treatments according to experimental design Maintain access Adjust management plans based on project results Help conduct tours
Forest Engineering Research Institute of Canada	Compare costs and productivity among treatments Produce technical reports
Ontario Ministry of Natural Resources	Lead science aspects of silviculture, succession, and soil dynamics Develop experimental design and monitoring protocols Manage project database Maintain web site Produce newsletter articles, technical reports, and journal papers Help conduct tours
Canadian Forest Service	Lead science aspects of biodiversity indicators (carabid beetles, spiders) Produce technical reports and journal papers
Lake Abitibi Model Forest	Lead marketing, training, and education Liaise with local stakeholders (First Nations, resource users, educational, recreational and municipal organizations) Link to national Model Forest Network Produce newsletter articles Help conduct tours
Upper Lakes Environmental Research Network	Administer project Manage finances Develop partnership agreement Facilitate communication and reporting
Sault College	Incorporate information from project into course curricula Provide field equipment through Canada Foundation for Innovation and Ontario Innovation Trust grants

Domtar sites. However, advance regeneration treatments were eliminated when pre-treatment surveys revealed inadequate stocking.

While acknowledging the need to be flexible enough to accommodate operational constraints, partners ensured that critical aspects of the experimental design (e.g., randomization, replication, and consistent plot size) remained intact. This approach enhances credibility of outcomes in active adaptive management projects (Halbert 1993, Sit and Taylor 1998).

Although adaptive management experiments are commonly implemented at landscape scales (Holling 1978, Lee 1999), smaller scales are appropriate for some management questions (Walters 1997b, Ritchie and Harcksen 1999, Gray 2000). In this case study, replicated experimental units were defined at the stand level. The 16- to 20-ha treatment plots were large enough to reveal differences in many ecological processes, but small enough to permit regular monitoring of ecological indicators. Designing treatments at the scale of forest operations also eliminated the need to extrapolate economic and silvicultural results from small research plots to operational-scale practices.

In some jurisdictions, strict environmental legislation allows little latitude for practising adaptive management (Stankey *et al.* 2003). Fortunately, conforming to provincial guidelines for protecting wildlife habitat, riparian zones, and soils did not unduly constrain treatment innovation in this study.

Conceptual models

Formal scenario planning and modelling may benefit adaptive management (Holling 1978, McLain and Lee 1996, Walters 1997b, Dewhurst *et al.* 1999, Lee 1999, MacLean *et al.* 1999, Rempel *et al.* 1999). However, since resource managers often do not have access to advanced analytical tools and expertise, the modelling component of adaptive management may be less formal (Rogers 1998, Gray 2000). Simple models are more attractive to resource managers and are usually all that can be developed, given the available data (Walters 1986). In this case study, quantitative modelling would be challenging because appropriate boreal mixedwood models and stand dynamics data are not available in Ontario. Thus, a conceptual modelling approach was used to generate hypotheses about indicator responses to help discriminate among treatments. Following are the main hypotheses being tested:

1. Proactively managing for boreal mixedwood stands (in this case, equal stocking of conifer and hardwood crop species) increases total volume yield compared to managing only for conifers.
2. Conifer regeneration in mixed stands performs better (survival, height growth, and quality) when conifer and hardwood crop trees are arranged in mosaics of alternating patches than when they are intimately blended.
3. Partial cutting is less effective than applying herbicide for enhancing the survival, height growth, and quality of conifer regeneration in boreal mixedwood stands.
4. Costs of producing species mixtures are moderately higher than costs of producing pure conifer stands.
5. Ecological indicators, such as plant species diversity and pools and cycling rates of soil elements, are more favourable in young managed mixedwood stands than in young conifer plantations on similar sites.

Response indicators

To maintain relevance and cost-effectiveness, adaptive management monitoring should be restricted to indicators

that will help guide adjustments to policies and practices (Holling 1978). At the planning workshop, many potential silvicultural, economic, and ecological indicators were screened down to a few that were operationally feasible and acceptable to all partners.

Resource managers assigned highest priority to silvicultural and economic indicators. They emphasized that although other indicators are theoretically attractive, they cannot be reliably measured in normal operations because of limited expertise and funds. Including indicators routinely assessed by resource managers increased the likelihood of information transfer and adoption of the adaptive learning process. Silvicultural indicators being assessed in this case study include regeneration composition, stocking, and height growth. Economic indicators include time and cost estimates for all treatment components.

The low-intensity, short-term regeneration assessments routinely conducted by forest companies may be inadequate for assessing ecological responses. Thus, ecological indicators were added to permit testing hypothesis no. 5. These indicators are less characteristic of adaptive management initiatives than the operationally-oriented indicators more familiar to resource managers (Holling 1978). Thus, the partners agreed that ecological indicators would be first to be eliminated if funding decreased. Ecological indicators being assessed include microclimate, vegetation succession, soil nutrient dynamics, and invertebrate abundance and diversity.

Indicators will be monitored at least until successional trajectories are defined. After three years, the appropriateness of some treatments for future management plans may be apparent. After 10 years, the degree of success of the mixedwood practices (hypotheses 2 and 3) should be clear. This could also serve as a "make or break" decision point for experimental treatments. If a treatment fails to generate the expected structure, follow-up interventions could be prescribed to recover the intended objective and limit the risk of productivity loss.

Consensus was achieved on which response indicators to use, but not on the level of each indicator that would be required to demonstrate treatment success. Thus, the treatments will be evaluated relative to one another, but not in relation to an absolute performance scale for each response indicator. Since tradeoffs among silvicultural, economic, and ecological effectiveness of treatments are likely, local management planners must decide which treatments best meet their overall objectives.

Considering the unpredictable economic climate, partners attempted to be realistic about the scale of the management experiment that could be maintained over the long term. They developed an alternative indicator monitoring program that allowed the initiative to be downsized rather than terminated in the event of major funding constraints. Progressive reductions to indicator monitoring intensity would be made in the following order: Invertebrates, microclimate, soil nutrients, vegetation succession, all economic indicators, regeneration height growth, and finally, all remaining indicators at the Domtar site.

Implementing the Strategy

According to Walters (1997a), adaptive management projects seldom proceed from the planning stage to field experimentation, and they may become trapped in an apparently endless process of model development and refinement. In this case study, industry partners were less interested in forging an elaborately designed initiative than in rapidly improving management by addressing long-standing questions. Some were driven by their operating plan timelines and were reluctant to prolong the design phase. Thus, implementation was facilitated by abbreviating the modelling component and treating adaptive management as a mechanism to support rather than disrupt the core business of each partner.

Changing market conditions produced some risk to treatment integrity. For example, Domtar was temporarily unable to utilize both conifers and hardwoods from its study site, but this issue was resolved prior to harvesting.

It was difficult to implement the treatment packages and subsequent monitoring exactly as planned because of unexpected variations in topography and stand types, limitations of existing equipment, lack of operator experience with modified harvesting, labour union constraints on operator selection, and greater than anticipated loss of usable area to roads, landings, and slash piles. More accurate treatment implementation may have been possible through strict monitoring of operators by researchers, but in keeping with the adaptive management approach, resource managers were responsible for implementing treatments (Table 1).

As the project evolved, some team members were replaced by new staff, whose opinions on management approaches differed from the original consensus. Altering treatments in an attempt to re-establish consensus was avoided in favour of maintaining the integrity of the original design.

Partners learned the importance of adopting a flexible attitude and developing backup plans for activities such as plot establishment and monitoring because some treatments had to be modified to suit operational constraints. For example, the planned harvest corridor width was increased to accommodate post-harvest herbicide spraying and some access road construction and site preparation was delayed. Also, one of the original project sites was harvested prematurely because of changes to operating plans, requiring an urgent survey to locate an alternate site.

Forest companies generally establish road access immediately prior to harvesting allocated areas, leaving insufficient time for survey crews to obtain pre-harvest data and evaluate the appropriateness of prescribed treatments. All active adaptive management initiatives in forestry should address this issue in the design step. In this study, crews increased the data collection period by using boats and all-terrain vehicles to access the allocated stands prior to road construction.

Since adaptive management projects commonly include innovative treatments, prior regulatory approval must be obtained to implement practices that are non-standard or not described in the original management plan. In this case study, requesting approval for pre-harvest herbicide spraying from the Ontario Ministry of the Environment several months in advance ensured that treatment application did not have to be delayed pending approval.

Monitoring Response Indicators

Maintaining a reasonable sampling intensity across large treatment areas for long durations is necessary to obtain results that are sufficiently reliable to support policy adjustments (Holling 1978, Walters 1986, Halbert 1993). Since the monitoring step can be extremely costly (Walters 1997a), it is a vulnerable link in the cycle. In this case study, funding for monitoring only permits a regeneration sampling intensity of 1%, and long-term

funding is unstable. While the implementation step is also expensive, its costs are short-term and addressed largely through in-kind contributions of industry partners. In contrast, success of the monitoring step relies on long-term cash flow from partners and external funding agencies. Obtaining sustained funding is challenging because all participating agencies can only commit funds on an annual basis, and continued constraints imply reduced funding in successive years of the project. Furthermore, external funding secured to establish the initiative may not be available to support monitoring and evaluation.

The potential for success in the monitoring step has been enhanced by developing an alternative, scaled-down monitoring program (as described under Designing a Strategy), relaxing rigour of sampling design, and ensuring a key role for resource management partners. Many elements of this strategy are appropriate for adaptive management (Taylor *et al.* 1997) but may be unacceptable in a more tightly controlled research trial.

Collaboration among several researchers on the project team increased the number of response indicators measured and the likelihood of detecting ecosystem effects of the experimental practices. However, as in other large-scale field studies, the potential for operational difficulties increased with the number of collaborators. For example, maintaining proximity of sample plots among collaborating studies for data sharing purposes increased the risk of damage to the plot infrastructure and sample material by multiple field crews.

Evaluating Responses and Adjusting Policies/Practices

Assuming all treatment replications remain intact, no technical barriers to evaluating resource responses are anticipated. Standard analysis of variance, analysis of covariance, or nonparametric equivalents will be used to compare how treatment packages affected the silvicultural and ecological indicators. When multi-year data are available, time series analyses will be conducted to test for differences in response trajectories among treatments. Other statistical techniques, such as multivariate regression and ordination, will be used to examine relationships among ecological indicators. Monitoring data will be available for refining mixedwood growth trajectories in the Strategic Forest Management Model, which is used by regional management planning teams in Ontario to project stand structure development for candidate management alternatives (OMNR 1996).

Ontario has recently released its first legislatively regulated guide for boreal mixedwood management (OMNR 2003b). The guide relies heavily on information from other jurisdictions because little work has been conducted on boreal mixedwood management in Ontario. Since the guide will be reviewed on a five-year cycle (OMNR 2003b), there will be opportunities to revise it based on evaluations of treatments in this study. For example, data will be available on the effectiveness of partial cutting for maintaining the conifer component on specific ecosites. The guide permits innovative treatments to be applied operationally under the "developmental" code if they are being experimentally investigated in the province (OMNR 2003b).

Abitibi-Consolidated and Domtar will also adjust mixedwood practices in their forest management plans, based on new understanding acquired in this case study. These commitments facilitate closure and reinitiation of the adaptive management cycle. This iterative learning process should improve the commercial productivity and ecological sustainability of the affected boreal mixedwood stands over time.

Not all of the knowledge gained through the adaptive management process will be used by provincial policymakers because public resource management agencies must synthesize all available information to address many competing interests. Economic factors may prevent forest companies from implementing some innovative, environmentally desirable treatments that meet management objectives. However, partners understand the risks associated with maintaining existing boreal mixedwood practices that have highly uncertain outcomes. Furthermore, companies may adjust practices to demonstrate adherence to the adaptive management principle of continual improvement, which is consistent with requirements for sustainable forest management certification (Canadian Standards Association 2002).

The evaluation and adjustment steps should address not only the effectiveness of the specific treatment packages in achieving target stand structures, but also the effectiveness of the active adaptive management process in promoting regular improvement of policies and practices. A formal evaluation of the process will be conducted when all steps of the adaptive management cycle are complete and the extent of adjustments to policies and practices is apparent.

Building and Maintaining the Partnership

While the previous sections addressed issues experienced or anticipated in each step of the active adaptive management cycle, this section focuses on the challenges involved in building and maintaining an effective adaptive management partnership.

Initial team membership

The success of an adaptive management initiative may not be enhanced by increasing the number of partners because large partnerships can become unwieldy and inefficient (Grumbine 1997). However, it is important to include diverse competencies and define roles and responsibilities of all participating agencies (Holling 1978, Walters 1986, Taylor *et al.* 1997). McLain and Lee (1996) emphasized the importance of diversity by suggesting that relying on a single stakeholder for monitoring and evaluation can result in the withholding of information unfavourable to the data keeper's interests.

In this case study, team members from industrial, government, not-for-profit, and academic sectors are contributing expertise in project management, experimental design and analysis, management planning, field operations, and technology transfer (Table 1). Participation of partners skilled in coordinating project teams, facilitating communication, liaising with funding agencies, and managing budgets has enabled resource managers and researchers to concentrate on technical tasks. Although including a diversity of partners has increased the potential for conflict over objectives and approaches, it has also added synergy and credibility that helps attract external funding. Participation of two forest companies with different management objectives should increase the applicability of the results.

Project initiators had to address an initial perception on the part of some potential team members that active adaptive management represents a threat to conventional profitable practices and human and financial resources of participating agencies. In contrast to other adaptive management initiatives (Walters 1997a, Gray 2000), no concerns were expressed

that the experimental practices may represent a threat to the ecosystem. This may be explained by the agreement among participants to implement remedial treatments if monitoring reveals unacceptable outcomes.

Since adaptive management demands time, resources, and creative energy, most potential partners considered both the costs and benefits of participating in this project. For example, resource managers considered the likelihood that cost-effective techniques for obtaining desired stand structures would be identified, and researchers considered whether silvicultural and ecological knowledge would be advanced. In other adaptive management projects, the commitment of researchers declined because of the lack of traditional science outputs (Gray 2000). This implies that conventional staff performance measures for resource managers and researchers may be inappropriate for adaptive management, which is a blend of management and science (Gray 2000).

Leadership

Several of the project's initiators were adaptive management champions and contributed the sustained effort needed to overcome the multiple barriers typical of such initiatives. This case study has shown that initiators must be prepared to assume the roles of leaders and technical coordinators. They must also train partners and supporters in the concepts of adaptive management to ensure a common understanding of the benefits and approaches.

Scientists may not be the most effective leaders and champions of adaptive management initiatives because their training as neutral sceptics conflicts with promotional roles. Resource managers are the logical leaders in adaptive management projects (Lee 1999) and some have risen to the challenge (Al-Pac 2002). In this case study, more proactive leadership by forest industry partners is being encouraged to increase their ownership and application of the results. However, reversion to the more traditional model of researchers conducting an experimental study and resource managers playing a support role has been difficult to resist. This science-driven model is common in large interdisciplinary projects that aim to reduce management uncertainties (Cissel *et al.* 1998, Aubry *et al.* 1999, MacIsaac *et al.* 1999).

Team renewal

Changes in team membership are inevitable in a long-term adaptive management project involving several collaborating agencies. In this case study, staff turnover made it difficult to maintain an adaptive management champion in every participating agency. This weakened the original sense of ownership by all agencies and necessitated periodic training of new members in the technical and philosophical underpinnings of adaptive management.

Staff changes and the emergence of other priorities within participating agencies meant that roles and responsibilities accepted by the original participants could not always be fulfilled. A key challenge is maintaining the long-term active participation of all partners, who are often overwhelmed by competing demands on their time.

Ideally, this project would be conducted by a team of adaptive management advocates who remain together for the long term. However, it may be difficult to retain members because adaptive management initiatives are challenging to organize and implement and may produce few deliverables in the early stages. It may be more reasonable to expect that much of the required expertise will be provided by temporary team members contributing at key points in the cycle. Such an arrangement would allow participants to produce deliverables that are compatible with their existing job requirements.

In this initiative, a formal partnership agreement documents objectives, methods, outputs, and roles and responsibilities, and commits each participating agency to replace representatives who are reassigned. However, such an agreement is difficult to enforce, perhaps because providing for disciplinary measures is not a priority in a team-building process that relies on trust among all participants. Furthermore, staff reductions may limit the ability of partnering agencies to identify replacement members. Since effective team dynamics require a group of like-minded adaptive management proponents, individual networking may be more important than formal assignments when teams are being assembled or renewed.

Operating protocols

Cooperation and consensus-building among participants are important to the success of an adaptive management initiative (McLain and Lee 1996, Taylor *et al.* 1997, Rogers 1998). Although a collaborative approach complicates experimentation, partners with dissimilar objectives must work together for the process to produce reliable knowledge (Lee 1999). This approach can be represented by a cycle of actions corresponding to the steps of the adaptive management cycle (Fig. 2):

1. Consulting all stakeholders ensures relevant problems are selected and fosters an atmosphere of trust among partners, without which the adaptive management initiative cannot succeed.
2. Skilfully coordinating the numerous design elements may be effectively and efficiently accomplished in facilitated workshops.
3. Communicating operational obstacles and consequent design changes ensures that all partners understand and fulfill their roles in project implementation.
4. Collaborating is essential in the monitoring step to ensure that all required data are collected on schedule and shared among partners.
5. Comparing results among collaborators' sub-studies and comparing outcomes to predictions increase the likelihood of reliable treatment evaluations.
6. Committing to improve policies and practices based on new understanding helps ensure the goals of the active adaptive management initiative will be met.

Since adaptive management involves risk and uncertainty, building mutual trust among partners is essential (Grumbine 1997, Gray 2000, Stankey *et al.* 2003). In this study, developing trust between industry resource managers and provincial government researchers could have been challenging because the provincial government develops and enforces forest management regulations. However, adopting a consensus-based approach encouraged acceptance and ownership of the process and its outcomes by all partners. Participation and mutual trust were increased by agreeing that all partners would contribute resources and share data and outputs. Ensuring that all partners had roles in determining the key uncertainties to be addressed and treatments to be tested increased the likelihood that they would adjust policies and practices following treatment evaluation.

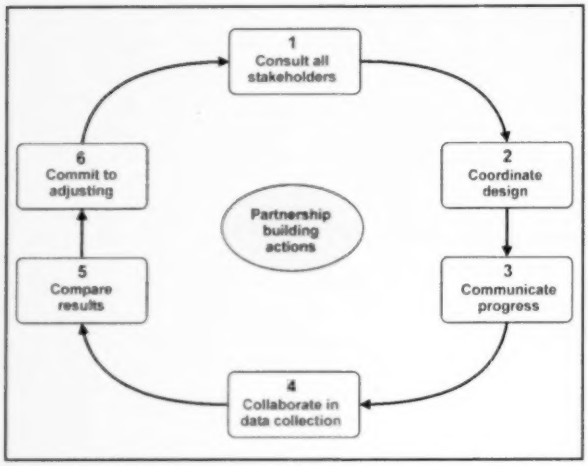

Fig. 2. Steps for building and maintaining a partnership, corresponding to those of the adaptive management cycle shown in Fig. 1.

Potential Barriers and Bridges

The experience of the Adaptive Management Areas (AMAs) in the Pacific Northwest illustrates typical barriers and bridges to implementing adaptive management. In 1994, 10 AMAs were established in Oregon, Washington, and California to address ecological, economic, and social issues arising from reduced timber harvests from federal forest lands (Stankey and Shindler 1997). Progress was hindered by scarce resources, limited marketing ability for leveraging funds, frequent staff changes and apathy in participating agencies, lack of functional and supportive social networks, and inadequate understanding and acceptance of adaptive management principles by partners. Furthermore, the risk-averse attitudes of most participating resource management agencies have restricted learning opportunities by limiting innovation (Gray 2000, Stankey *et al.* 2003). In AMAs, trial-and-error learning is more common than experimental probes (Lee 1999).

The above barriers are similar to those encountered in other adaptive management initiatives (Gray 2000). Recommendations for overcoming them include establishing stable funding, promoting training and development opportunities for staff in partnering agencies, replacing a prescriptive approach with an enlightened risk-taking approach, and encouraging collaboration among regulatory, management, and research agencies (Stankey *et al.* 2003).

In this case study, institutional and economic barriers have been more troublesome than technical barriers because the origins and solutions of the former are usually beyond the direct control of the adaptive management team members. Opportunities for conflict were greatest in the assessment and design steps of the adaptive management cycle, when values, objectives, and approaches were being determined. Once consensus on these issues was reached, the implementation and monitoring steps proceeded with minimal contention. This experience highlights the importance of allocating sufficient time to the initial steps to develop a durable consensus on long-term strategies.

Convincing key decision-makers in partnering agencies to support the initiative was critical to its long-term survival. This often entailed presentations of the rationale, approach, and expected benefits of active adaptive management, primarily by the science partners. Linking objectives to current or emerging issues helped gain support. All parties involved must understand the payoffs from increased knowledge through experimentation if this approach is to become an accepted means of reducing uncertainty in natural resource management (Halbert 1993).

Although proponents of active adaptive management must adopt a long-term perspective, external funding and executive support within participating agencies are usually offered incrementally upon delivery of short-term products. Thus, the results of this study will be marketed to potential supporters as soon as they are available.

The diversity of challenges emphasizes that prior to launching an adaptive management initiative a group of partners should draft potential solutions for anticipated social, economic, institutional, and technical barriers (Table 2).

Summary and Conclusions

Despite numerous barriers (Table 2), the SLAM partnership has maintained progress by promoting flexibility, trust, and consensus-building. Operational-scale treatments aimed at reducing boreal mixedwood management uncertainties have been implemented and an extensive monitoring program has been initiated. There are no major technical obstacles and the partners are enthusiastic about the potential for rapid increases in understanding. Issues causing most concern are those beyond the direct control of the partners, such as instability of long-term funding and resistance by some resource management agencies to implementing risky, non-standard practices as part of the learning process.

Considering the challenges of active adaptive management and the levels of resources and sustained effort required to overcome them, this formal approach to iterative learning is not always appropriate. However, it should be considered when management uncertainties become economic and ecological issues, but laboratory-style precision seems infeasible and trial-and-error seems too risky (Lee 1999).

The classical version of active adaptive management, as developed by academics for natural resource applications, includes an array of components and processes that could be intimidating (Walters 1986). For example, resource managers may not have access to specialized modelling expertise and may lack the discretionary time required to build interagency partnerships, seek long-term funding, and coordinate intensive monitoring. However, Gray (2000) advocated simplifying the formally structured, expert-driven, scenario-modelling approach to adaptive management, and this case study demonstrates that it can be applied in a streamlined form that is appropriate for local management units.

Important benefits may be realized by implementing only some elements of active adaptive management. For example, promoting more direct working relationships between resource managers and researchers and coordinating their scales of operation would greatly enhance research relevance and management effectiveness.

Researchers know the importance of ensuring that scarce funds are used to address the highest-priority issues of their clients. Active adaptive management links research and management, establishing client receptivity of the results early in the project. Results are considered relevant because resource manage-

Table 2. A key barrier and suggested bridge for each step in the Stand-Level Adaptive Management case study's active adaptive management cycle

Step	Barrier	Bridge
Assess problem	Difficulty agreeing on relative importance of economic and ecological values	Limiting the number of partners and using consensus-based decision-making
Design strategy	Resistance from some partners to implementing innovative, non-standard practices	Building a team of like-minded adaptive management proponents who tolerate some risk
Implement strategy	Staff changes disrupting original consensus and fulfillment of roles and responsibilities	Addressing protocols for team member replacement in a partnership agreement
Monitor indicators	Lack of funds	Gaining the support of high-level decision-makers in partnering agencies
Evaluate strategy	Lack of reliable quantitative models of long-term treatment effects	Dedicating part of a modeller's time to the initiative for its duration
Adjust policies and practices	Political or economic factors that curtail application of results	Ensuring partnering agencies understand risks of maintaining traditional policies and practices that have uncertain outcomes

ment and policy clients strongly influence the issues being addressed, and the large-scale experimentation eliminates the need to extrapolate treatment results from small research plots to operational practices. Thus, active adaptive management serves as a model of how to increase the relevance and application of results in all research projects.

The experience documented in this case study should help other partnerships to implement local active adaptive management initiatives. The adaptive management process requires each partnership to define specific issues through consultation and consensus-building. Candidate issues that are appropriate for the adaptive management approach include mitigating effects of climate change, testing provincial management guidelines, and demonstrating sustainability of practices for certification.

Resource management agencies are generally structured to maintain control over resources, information, and people, rather than to respond to new learning (Grumbine 1997). Thus, a broader application of active adaptive management in Ontario will require a comprehensive strategy endorsed by senior decision-makers in leading resource management agencies. To be successful, this strategy must identify how to promote the following:

- Training of staff in active adaptive management protocols.
- Willingness to admit uncertainty of outcomes of policies and practices.
- Cooperation among resource management agencies.
- Stability of long-term funding.
- Innovative, non-standard management approaches.
- Periodic adjustment of policies, guidelines, and practices.

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